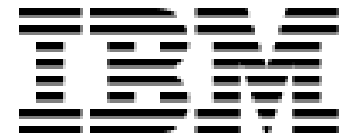




The Little-Endian OpenPOWER Software Development Environment

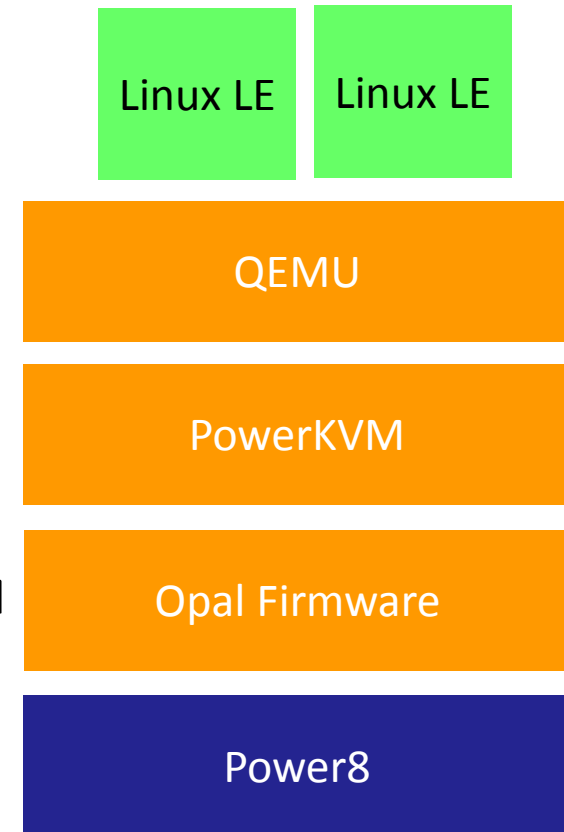
Dr. Michael Gschwind
Senior Technical Staff Member & Senior Manager
IBM Power Systems

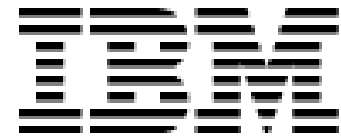




OpenPOWER ecosystem

- Enable rich ecosystem of hardware vendors
 - Standardized hardware interfaces
 - ⇒ Common, open firmware interfaces
- Open source system software stack
 - Data center operators rely on tuning SW stack
 - Enable server ODM vendors to create offerings
 - ⇒ Operating environment built on Linux and KVM

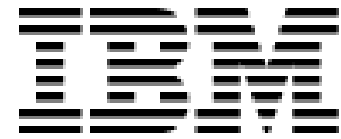




A New OpenPOWER Linux Environment

- OpenPOWER is not traditional Power Linux with a new name
 - Significant discontinuity and fresh start
 - ⇒ new environment “ppc64le”
 - Firmware, Hypervisor, data layout, source code, ABI, APIs

- What changes for application developers?
 - Byte order
 - New ABI
 - Vector programming API

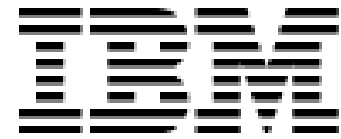


The New Byte Order

- ⇒ Little-endian data format and programming interfaces
- Simplify porting of applications previously locked to Intel x86
 - Large-scale data center applications
 - Application source code dependences
- Access data repositories storing binary data written by Intel x86
 - In-storage data base formats
 - Data sharing with mobile devices
- Simplify data sharing with I/O devices originally from LE ecosystems`
 - Easily exploit I/O and accelerators designed for PCs and mobile devices



The New OpenPOWER Application Binary Interface (ABI)

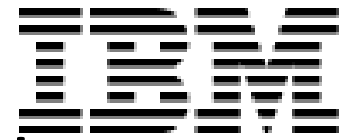


- Optimizations driven by hardware and software evolution
 - Align with the broader ecosystem
 - Create hardware optimization opportunities and synergies
- Optimize for modern code patterns
 - More classes, abstraction
 - Shorter function lengths
 - More indirect calls
- New capabilities as delta over starting point: PPC64 / AIX ABI
 - Established, tested production code
 - Commonality and maintenance across LE, BE and AIX where feasible
 - Minimum disruption for tooling: GCC, XL, Java, LLVM, libffi, PyPy, ...



The new ABI

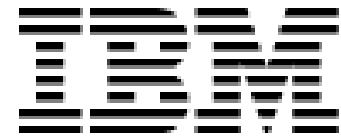
- Application development: no change
 - for applications written in Fortran, Pascal, C, C++, C#, Java, Python, Ruby, Spark
 - minimal change (0-4 lines) for assembly programs
- Align with other Linux environments to simplify migration
- Simpler and shorter code
- Improved performance and ease of adoption
 - During initial LE Linux bringup, 40,000 packages ported over short period



ABI Improvements: simplify and accelerate

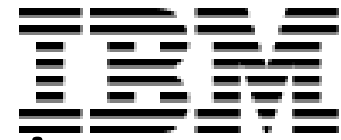
- Global data management with the Global Offset Table
 - Initialize pointer to GOT without functions descriptors
 - Optimize GOT pointer update on cross-module calls
 - Expand addressing range with “Medium Code Model”
 - Exploit Displacement Fusion and avoid GOT overflow code
- Pass more registers in their native registers
 - Reduce abstraction penalty (“same performance as builtin types”)
 - OO languages wrap types in abstract class
 - Previously classes handled differently from builtin types
 - ELFv2 passes up to eight class members in registers
 - Return function results in same register(s) as first input parameter





Medium Code Model

- “Medium code model” addresses growing application size
 - Expand GOT data dictionary to up to 4GB
- Avoid expensive GOT overflow > 64KB (8k variables) per module
 - Size originally set to POWER ISA offset size (16b)
- Enable applications with up to 500M variables per module
 - “Beyond RISC” using Displacement Fusion in Power8



Beyond RISC: Displacement Fusion

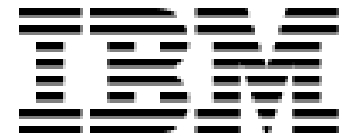
- Combine multiple instructions into single internal instruction
- Compound instruction executes as a single hardware operation
- Increased addressing range with RISC fixed-width instr. advantage

```
addis r3=r2, D1@ha  
ld    r3=r3, D1@l
```

Displacement fusion → `ld r3= r2, D1`



Example OO method with abstract data types

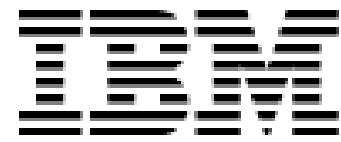


```
199|                PDEF      _vec8_mulfp
      |                PROC      #retvalptr_49,left,right,gr3,gr5-gr10
      0| 0031A0 stdu      F821FF31  1      ST8U      gr1,#stack(gr1,-208)=gr1
206| 0031A4 addi      380000C0  1      LI          gr0=192
203| 0031A8 addi      38810130  1      LA          gr4=right(gr1,304)
      0| 0031AC std       F8C10118  1      ST8         left(gr1,280)=gr6
      0| 0031B0 std       F8A10110  1      ST8         left(gr1,272)=gr5
      0| 0031B4 std       F8E10120  1      ST8         left(gr1,288)=gr7
      0| 0031B8 std       F9010128  1      ST8         left(gr1,296)=gr8
      0| 0031BC std       F9210130  1      ST8         right(gr1,304)=gr9
202| 0031C0 addi      38A10110  1      LA          gr5=left(gr1,272)
      0| 0031C4 std       F9410138  1      ST8         right(gr1,312)=gr10
203| 0031C8 lxvd2x    7C202698  1      VLQD        vs1=right(gr4,0)
202| 0031CC lxvd2x    7C002E98  1      VLQD        vs0=left(gr5,0)
203| 0031D0 addi      38C40010  1      AI          gr6=gr4,16
202| 0031D4 addi      38850010  1      AI          gr4=gr5,16
205| 0031D8 xvmulsp   F0400A80  1      VFM         vs2=vs0,vs1,fcv
203| 0031DC lxvd2x    7C203698  1      VLQD        vs1=right(gr6,0)
202| 0031E0 lxvd2x    7C002698  1      VLQD        vs0=left(gr4,0)
206| 0031E4 xvmulsp   F0000A80  1      VFM         vs0=vs0,vs1,fcv
205| 0031E8 addi      388000B0  1      LI          gr4=176
205| 0031EC stxvd2x   7C412798  1      VSTQD      result.m128_0(gr1,gr4,0)=vs2
      0| 0031F0 ori       60420000  1      XNOP
206| 0031F4 stxvd2x   7C010798  1      VSTQD      result.m128_1(gr1,gr0,0)=vs0
207| 0031F8 ld        E80100B0  1      L8         gr0=result(gr1,176)
207| 0031FC std       F8030000  2      ST8         #retval_49(gr3,0)=gr0
207| 003200 ld        E88100B8  1      L8         gr4=result(gr1,184)
207| 003204 std       F8830008  2      ST8         #retval_49(gr3,8)=gr4
      0| 003208 ori       60420000  1      XNOP
207| 00320C ld        E80100C0  1      L8         gr0=result(gr1,192)
207| 003210 ld        E88100C8  1      L8         gr4=result(gr1,200)
208| 003214 addi      382100D0  1      AI          gr1=gr1,208
207| 003218 std       F8030010  1      ST8         #retval_49(gr3,16)=gr0
207| 00321C std       F8830018  1      ST8         #retval_49(gr3,24)=gr4
208| 003220 bclr     4E800020  0      BA         lr
```

- Work instructions in green
- Overhead due to passing abstract data types via memory in red

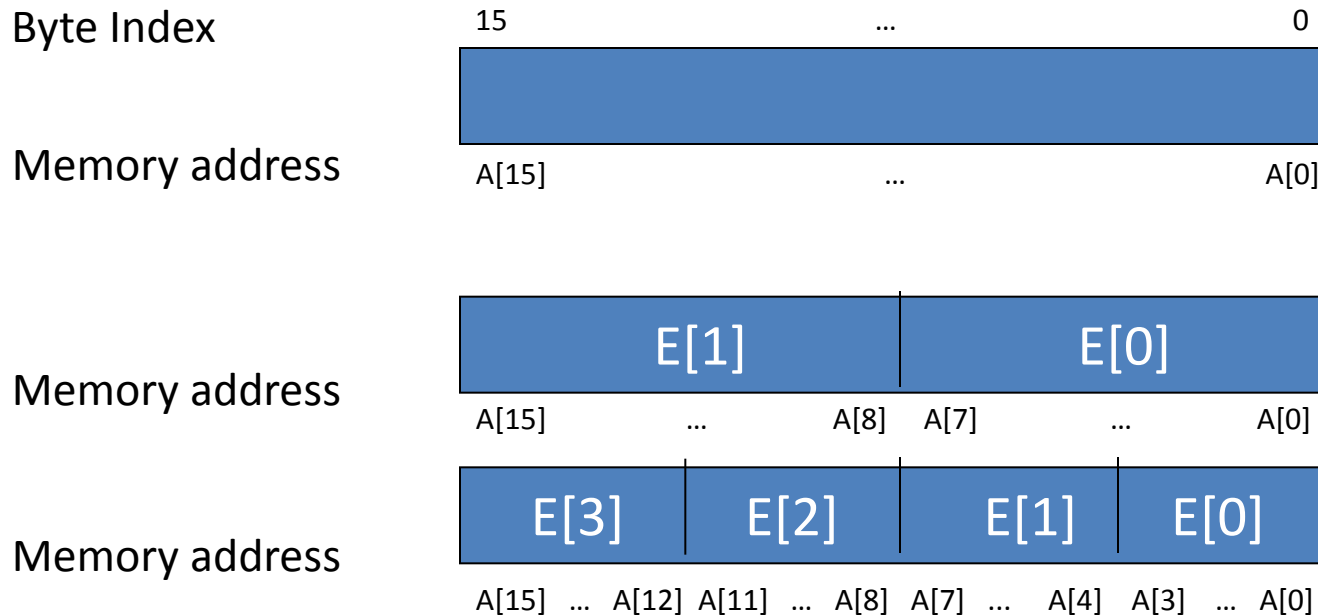
Courtesy of Ian McIntosh,
IBM Toronto



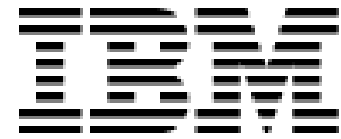


The Little-Endian Vector API

- Vector API builds on OpenPOWER Little-Endian Data Model
 - Focus on programmability – consistent little-endian view
 - Focus on ease of sharing code with other little-endian ecosystems



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Little-Endian Vector API Implementation

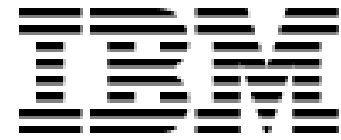
- Common Vector Programming API across GCC, LLVM and XL
 - Vector builtins as operators
 - Enable compilers to optimize expressions with vector operators
- Vector API code models are programmer abstractions
 - Common LE/BE compiler backend...
 - ... recognizes and optimizes the different conventions

$$f^{-1}(s(f(x), f(y))) \Leftrightarrow s(x, y)$$

Technical details:

- “Supporting Vector Programming on a Bi-Endian Processor Architecture”, LLVM 2014
- “Bridging endian-dependent SIMD vector representation with compiler optimization”, PPOPP Workshop on Programming Models for SIMD/Vector Processing 2015





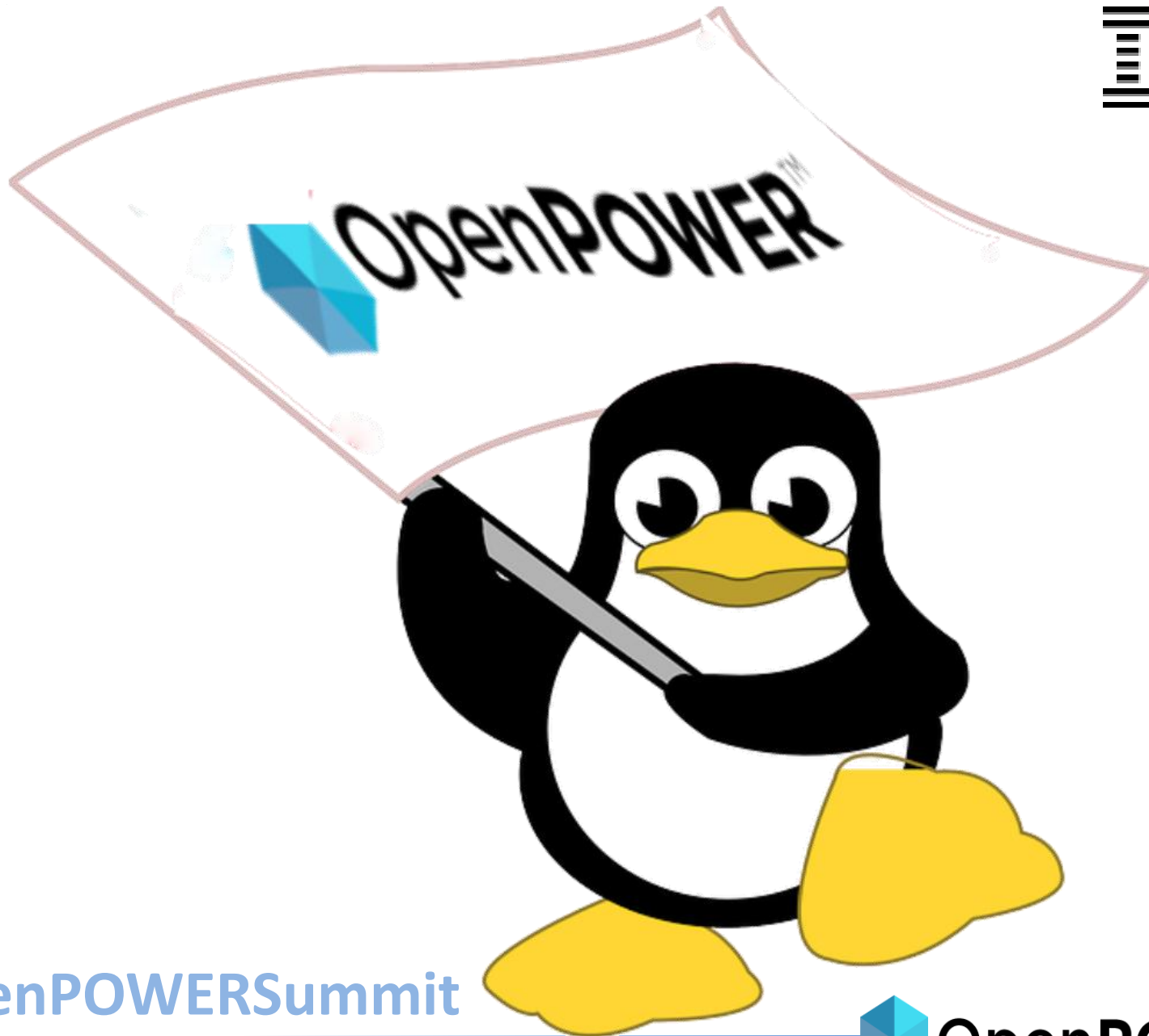
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- Collaborative innovation already changing industry
 - Major data center stakeholders joining OpenPOWER
 - Little-endian Linux on Power available from three major distros
 - ➔ Over 40000 open source packages and ISV applications ported
- Redefined software stack: Firmware, Hypervisors, OS, Applications
 - Little-endian data model for simplified application porting
 - New ABIs and APIs support developers in exploiting platform
- New OpenPOWER environment enables
 - Ease-of-use and out-of-box performance
 - Exploitation of new Power8 hardware features



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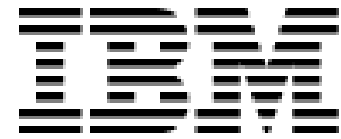
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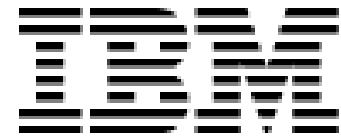
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